VOL. 4 NO. 3 MAR. 1987

COMPUTER DIGEST

A NEW KIND OF MAGAZINE FOR ELECTRONICS PROFESSIONALS

THE MC 68000

An in-depth look at a 68000-based computer you can build

BUILD A CLOCK BOARD FOR YOUR PC

Your computer will never forget what time it is!

THE PC-SIG LIBRARY

550 megabytes on a compact disc

A GERNSBACK PUBLICATION

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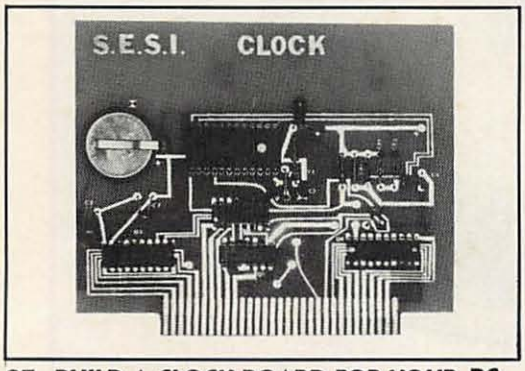

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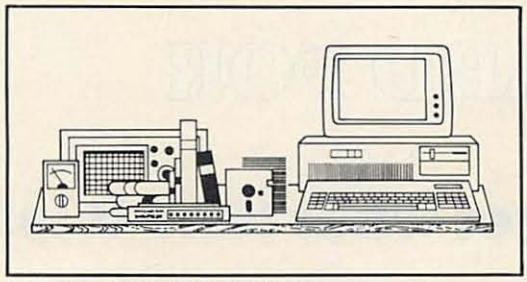

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ComputerDigest
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ADVERTISING SALES 516-293-3000
Larry Steckler
Publisher

NATIONAL SALES
Joe Shere
1507 Bonnie Doone Terrace
Corona Del Mar, CA 92625
714-760-8967

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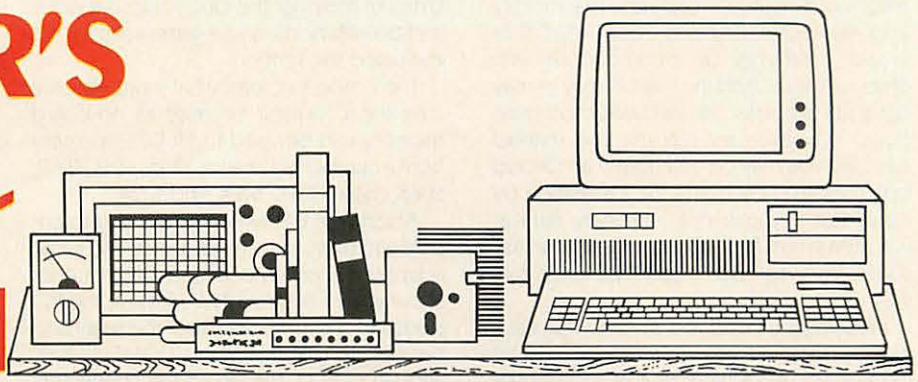


Welcome to the Editor's Workbench. In case you haven't noticed, **Computer-Digest** is changing. How? We're going to be following the PC market much closer than we have been. We're going to review the latest hardware and software. And we're going to provide exciting articles on both construction and theory. We have a bias—IBM and CP/M systems—but if you're interested in others, let us know. When we find significant interest in a product or topic, we'll get on the manufacturers and authors for samples and articles. And don't worry—we're not abandoning C-64's, ZX-81's, etc. We'll publish quality articles on those computers, too.

This month in our Hardware section we're going to look at several excellent expansion boards for the IBM-PC. In the Software section, we'll examine the PC-SIG library on CD-ROM (which contains the equivalent of more than 600 floppy disks!). And be sure to take a look at the Etc. section—Zenith has an interesting new computer. And there's a Hayes-compatible modem that runs on a nine-volt battery and is smaller than a pack of playing cards.

MEMORY-EXPANSION AND MORE FROM ORCHID, APPARAT, AND VERICOMP

It wasn't long ago—perhaps two years—that a "fully-loaded" expansion board (with a serial port, a parallel port, a game adapter, a battery-powered clock/calendar, and as much as 384K of RAM) cost half a kilobuck, or more. These days, for the same cash outlay, or less, you can get multi-function expansion cards that provide all the above, plus "productivity software," plus a megabyte or two of RAM.

More than a megabyte? How can an 8088 access that much memory? Besides, MS-DOS (and IBM's PC-DOS) can't access more than 640K of RAM—can it?

It can, and does. About a year and a half ago, Lotus Corporation (of spreadsheet fame) got together with Intel (of microprocessor and memory fame) and Microsoft (of operating-system and programming-language fame) and settled on an "interim" solution to the never-enough-memory problem suffered by all computer users. The big three came up with a hardware/software scheme for bank-switching up to eight megabytes of memory into a single, otherwise-unused 64K block of the 8088's address space. That type of expanded memory is variously called LIM (for Lotus, Intel, and Microsoft) or EMS (for Expanded Memory Specification). Whatever you call it, it can be tremendously useful—and not just for users of large spreadsheets. We'll discuss the technicalities of how it works in a future issue; for now, let's show how it can be put to use.

What's it good for? The same things that normal memory is useful for. You can, of course, use it with Lotus 123 to create larger spreadsheets. You can also use it to create RAM disks and printer buffers. The advantage of the RAM disk is that oft-used software can be downloaded from relatively slow disks (hard or soft) into EMS memory where it's available for instant use. And a printer buffer can store huge amounts of printer output in RAM and feed it the printer at its relatively slow rate. A modest printer buffer (64K) and a RAM disk can save you much time and aggravation.

In addition, more and more programs are able to take advantage of EMS memory for data and program storage, thereby allowing you more DOS memory (under 640K) for memory-resident programs and the like. In the memory-resident mode, for example, the Ready! outline processor leaves only a small program kernel in DOS memory, and it swaps the main program code and your data in and out of EMS memory as required. AutoCAD 2.5 uses EMS memory for storage of drawing vectors, thereby allowing much faster screen re-draws and the like. Again, the time you save can be enormous.

By now you're convinced (or should be) of the value of EMS memory, but you might be wondering whether you can get a chunk of it without mortgaging your grandmother. The answer is yes—definitely! you can now get a fully expanded multifunction board for what a partially expanded board cost just a few years ago—or even less. If you need only memory and no ports, etc., you're in luck, too.

Orchid's *Conquest*

Orchid Technology (47790 Westinghouse Drive, Fremont, CA 94539) has a high-quality line of turbo boards, enhanced display adapters, and multifunction boards. (See, for example, our review of the *PCturbo 286e* in the February issue.) Their *Conquest* multifunction board is a high-quality example of the type of product now available.

The *Conquest* includes a serial port, a parallel port, and a clock/calendar. No game adapter is included. In addition, the board can hold one megabyte of memory (or two megabytes, using an optional daughterboard). The memory can be used as DOS RAM, EMS RAM, or both. An additional daughterboard is available for interfacing to Orchid's *PCnet* local-area-network system.

The board itself is full-length, and it occupies a single slot. The serial-port connector is attached to the mounting bracket; the parallel-port connector must be installed in a separate rear-panel slot, if it is used.

In addition, *Conquest* includes software for print spooling, RAM disk, disk caching, and a special memory-resident time/date display, with alarm. Disk caching is a special software technique for speeding up operation of hard- and floppy-disk drives.

Installing some Orchid boards is not a pleasant task, mainly because Orchid uses automated intallation programs that modify your AUTOEXEC.BAT and CONFIG.SYS files in ways that may be incompatible with other software. And the manual may or may not spell out what the installation program does. However, by reading the manual carefully, you may be able to get an Orchid board running by doing the installation by hand. But if you're not intimately familiar with IBM sytem files, interrupts, and the like, you're likely to have trouble doing it that way.

Installing the *Conquest* is somewhat easier than installing other Orchid boards. To install it, you run a program that shows how to set the on-board jumpers. The jumpers show the *Conquest* whether some RAM is to be used for DOS or all for EMS, the 64K bank through which the EMS memory may be accessed, whether the ports and clock are enabled, and, if so, through which DOS communications channels (COM1 or COM2, LPT1 or LPT2), whether the ports may use interrupts, and, if so, which. DOS RAM can only be filled from the 256K point.

After running the first set-up program, you install the board in your PC, and then run a second installation program. It allows you to allocate EMS memory for the RAM disk, the print spooler, etc. Orchid's memory-allocation scheme is a bit unusual in that the print spooler, if used, must go in DOS memory; the RAM disk and disk cache can go in either DOS or EMS memory. After running the program, your AUTOEXEC.BAT and CONFIG.SYS files have been modified. You can re-run the program at any time, but you must use the old versions of those system files (which have been renamed with the extension .OLD).

The manual and installation procedure give you few hints about how much memory to allocate to which functions. If you're unsure, you can experiment without hurting anything. A knowledgeable friend or someone from a local computer club may be able to help, as may your dealer. But don't look to Orchid for support—it's hard to get through to their technical-support department, and they don't return telephone calls.

When you do settle on the right configuration, you'll understand what the EMS fuss is about. The *Conquest* currently lists for $395 with no RAM, $445 with 256K, $625 with one megabyte, and $865 with two megabytes; at press time it could be found discounted for about $220, without RAM. Adding a megabyte costs an additional $100. For even more memory (up to the eight-megabyte EMS maximum), multiple *Conquest's* can be installed in one system.

The Apparat *Limbo II*

Apparat, Inc. (6801 South Dayton, Englewood, CO 80112) sells a pair of boards for expanding the IBM-PC. One, the *Limbo*, contains only a clock/calendar and as much as two megabytes of memory; the other, the *Limbo II*, contains as much as 1.25 megabytes of memory, the clock/calendar, serial and parallel ports, and a game adapter. We evaluated the *Limbo II*.

The *Limbo II* is somewhat more versatile than the *Conquest* because its on-board memory can be used to fill DOS memory from a number of base locations (64K, 128K, 256K, 320K, 384K, 512K, and 576K).

A separate DIP switch allows you to enable and disable the clock, ports, and game adapter. Other jumpers and DIP switches allow you to set the RAM window, the I/O ports used by the card, and the serial and parallel port designations (COM1, COM2, and LPT1–LPT3). The board has connectors on the mounting bracket for the serial and game ports; the parallel-port connector must be attached through a separate cable to a vacant portion of the rear panel. You can connect an optional reset switch to a two-pin header block; especially useful to programmers, the switch works in conjunction with an optional RAM-resident program to provide a non-power-down reset for the time when a program goes astray.

Apparat's manual is not as well produced as Orchid's, but it is much easier to follow. Switch settings are shown clearly, the necessary changes to the system files are outlined clearly, and possible problems are anticipated. An appendix gives examples of using each of the supplied programs (the system drivers, several RAM-disk programs, several print spoolers, and several others.) No disk-cache program is supplied.

The board and supplied software worked with no hitches. With 256K of RAM the Limbo II lists for $299; with 1.25 megabytes of RAM, it lists for $499. The *Limbo* lists for $199 with 64K, or $549 with two megabytes of RAM.

Vericomp's *Breakthru/PC*

The *Breakthru/PC* from Vericomp (8825 Aero Drive, Suite 210, San Diego, CA 92123) is a full-length memory-only board; its RAM may be used only for EMS, not DOS, memory. However, it packs a walloping two megabytes on a card that costs just $398 with two megabytes of RAM, or $150 with no RAM. It comes with RAM-disk, print-spooler, and disk-cache software, as well as a memory-test program. Its manual is sparse but clear.

Conclusions

Whether you're new to the world of the IBM-PC or an old hat, there's an economical way to expand your PC. A memory-only board like the *Breakthru/PC*, or even the *Limbo*, with its clock/calendar, may be the best solution if you already have a fully loaded PC. But if you're starting from scratch, or need extra ports, both the *Conquest* and the *Limbo II* are good buys. The *Conquest* has slightly better software, but the *Limbo II* is more versatile in its ability to fill DOS memory.

10,000 PUBLIC-DOMAIN AND USER-SUPPORTED PROGRAMS ON DISK.

For several years a company called PC-SIG (1030D East Duane Avenue, Sunnyvale, CA 94086) has been marketing public-domain and user-supported software for the IBM-PC. As of this writing, their carefully selected library consists of more than 600 double-sided double-density diskettes—and more are being added all the time.

Each disk sells for $6; printed directories and a monthly newsletter are also available. Almost every conceivable type of program is included—everything from word processors and database managers to games to tutorials on various programming languages (BASIC, C, Pascal) to DOS tools to databases on structual-steel and magazine articles—and much more.

We thought it was time we took a look at the PC-SIG library, but that presented us with a problem. Normally we like to examine a single program, take it through its paces, find out its strong points, its weaknesses, its lovable quirks, and, if necesary, its not-so-lovable quirks. That procedure serves us most of the time—but not always. The usual program comes on a single floppy disk, or, at most, two or three. But what could we do when the software comes on more than 600 diskettes?

PC-SIG has had the intelligence to make their library available on CD-ROM. That 550-megabyte hunk of plastic made it possible for us to examine the PC-SIG library and extract many program and data files, some of which we've posted on the RE-BBS. (See the inside cover of Computer Digest for information on the RE-BBS.)

To access the disk, of course, you need a CD-ROM player. (Hitachi, Sony and Philips drives are supported.) In addition, you need an IBM-PC or compatible running PC-DOS (or MS-DOS) 3.1 or higher. After following the installation procedure, the CD-ROM appears as the next available logical drive. On our test PC-XT, that was drive D.

The new logical drive has several subdirectories, as shown in Fig. 1. The DOD (directory on disk) subdirectory contains search-and-retrieval information; the INFO subdirectory contains information about PC-SIG; and the BIBLE subdirectory contains the entire contents of the Bible. The other subdirectories each lead to separate subdirectories for each PC-SIG diskette. So, for example, the path to disk 432 would be:

```
 Volume in drive D is PC-SIG
 Directory of  D:\

DOD             <DIR>          9-14-86   2:20p
INFO            <DIR>          9-14-86   2:20p
1-100           <DIR>          9-14-86   2:20p
101-200         <DIR>          9-14-86   2:20p
201-300         <DIR>          9-14-86   2:20p
301-400         <DIR>          9-14-86   2:20p
401-500         <DIR>          9-14-86   2:20p
501-600         <DIR>          9-14-86   2:20p
601-700         <DIR>          9-14-86   2:20p
BIBLE           <DIR>          9-14-86   2:20p
       10 File(s)  43745280 bytes free

D>_
```

FIG. 1

```
.              <DIR>          9-14-86   2:20p
..             <DIR>          9-14-86   2:20p
README                2038    2-09-86  10:08p
1-100     UPP       123662    1-27-86   4:12p
101-200   UPP       117056    1-27-86   4:19p
DFIND     BAT           85    2-09-86  10:08p
INDEX     TXT        38338    8-06-86   9:34a
Q&A       TXT         5114    5-05-86   1:59p
PC-SIG    TXT          508    5-05-86   1:59p
ORDER     TXT         4049    9-13-86   3:23p
URESP     TXT          195    2-09-86  10:09p
SUBMIT    TXT         1758    2-09-86  10:09p
GO        BAT           28    2-09-86  10:09p
MORE      COM          384    2-09-86  10:09p
201-300   UPP       134596    1-27-86   4:26p
301-400   UPP       192808    1-27-86   4:37p
601-700   UPP         4071    1-27-86   4:55p
401-500   UPP       176150    1-27-86   4:46p
501-600   UPP       159388    1-27-86   4:54p
FILELIST  TXT       443996    9-13-86   3:13p
F         BAT           22    9-13-86   3:17p
       21 File(s)  43745280 bytes free

D>_
```

FIG. 2

\401-500\DISK432. Note in the photo that, even with all the above stored on the CD-ROM, there are still more than 43 megabytes of space remaining!

Scanning through 600 diskettes might seem to be a tedious job, especially when you consider that each diskette contains ten or twenty files, and often more. However, each "disk" contains a directory file (in ASCII), and the DOD subdirectory (shown in Fig. 2) contains a number of master catalog files (*.UPP) that can be searched with the MS-DOS FIND.COM program, or with several programs supplied by PC-SIG.

So locating programs of interest is not quite the chore it seems at first. However, the PC-SIG library is not completely indexed (as is another recent CD-ROM release, Groliers' *Electronic Encyclopedia,* a review of which will appear in these pages soon), so a fair amount of manual drudgework may be necessary if you want something specific, or if you want to make a thorough search.

Some people are skeptical about the quality of public-domain software; they wonder whether it is really as good as commercial software, and they may wonder whether it contains a "Trojan horse," a purposely destructive program.

To begin with the latter, PC-SIG checks all programs to make sure that no Trojan horses are distributed.

As for program quality, it varies enormously, but there is no doubt that the best programs in the PC-SIG library are as good as or even better than their commercial counterparts. It's hard to provide examples because, with a library of perhaps 10,000 programs, choosing examples is hard. However, we will mention two programs, both of which we use every day, that have become part of our MS-DOS toolkit.

Outline processor

The first is called PC-OUTLINE. (See Fig. 3.) As the name suggests, it is an outline program. It features drop-down menus, a built-in keyboard macro processor, the ability to open nine different files at once, each in a window whose size and location can be set by the user, extensive document-formatting commands, the ability to remain RAM-resident, and in that mode to import and export text directly to a word-processing (or other) program. It can also print files, or save them in ASCII, WordStar, and "Structured" files. The latter is used to exchange files with other outline processors. Tutorial and other information is also included with the package.

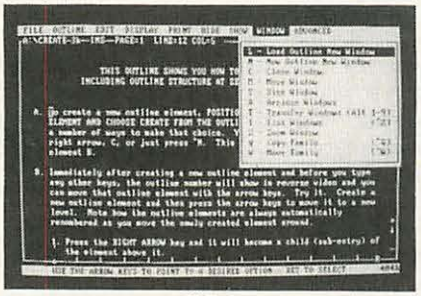


FIG. 3

In addition, PC-OUTLINE is fast—really fast—even on a standard 4.77-MHz PC clone. Its high speed proves that with proper programming techniques, a "lowly" 8088 really has enough power for word processing and similar applications—if the programmer knows what he (or she) is doing. If you've ever seen a program like Microsoft Word or Webster's New World Word Processor chugging along on a standard PC, you'll appreciate PC-OUTLINE's speed.

PC-OUTLINE is "user-supported," so the author expects you to send $50 if you use it. At $50, the program rivals or exceeds all the major commercially available outline processors. If you'd like to give PC-OUTLINE a try, order disk 480 from PC-SIG, or download PCO.ARC from the RE-BBS.

Command-line editor

Our other favorite program from the PC-SIG library is called CED, short for Command-line Editor. (We've also posted a copy of it on RE-BBS.) CED is a memory-resident program that, as its name suggests, allows you to edit commands at the DOS command line. To do so, you use keys in the cursor pad; the function keys no longer work. The left and right cursor keys move by character; CNTL-Left moves left by the word; CNTL-Right moves right by the word; Home takes you to the beginning of the line, and End takes you to the end; last, CNTL-End erases from the current position to the end of the line.

CED also keeps a stack of recently-performed DOS commands. Use the Up and Down arrow keys to move through the stack. When you find one you want, edit it in the usual fashion, and press Return when you're ready to execute it.

You may use CED to edit lines (and scroll through recently issued commands) anytime DOS is requesting input via function ØAh. Other than the DOS command-line input routine, DEBUG and EDLIN also use ØAh input.

You can also use CED to set up pseudo-DOS commands, or what CED calls a synonym. A synonym can be a single command (such as cd \letters\1987\march) callable by a short mnemonic ("M" for example).

A synonym can also be composed of several commands; CED thereby functions as a simple, but fast, batch processor. The advantage to using CED's batch synonym facility is that even short DOS batch files take up a great deal of space—4K on a standard PC-XT. With CED you can set up a single configuration file that contains your most-used DOS command strings arranged as CED synonyms and callable by a single letter, if desired. Letting CED do the work saves disk space and reduces clutter. And, because the disk is not accessed, synonym batch files run fast.

You can set the size of the command-stack buffer, the synonym buffer, and others. In addition, pressing CNTL-T (at the DOS prompt) will display buffer usage, defined synonyms, etc.

CED has a number of other advanced features, including the ability to add your own "internal" DOS commands, and complete documentation. It is available from PC-SIG on disk 535; we've posted a copy on the RE-BBS (download CED.ARC). The author of CED, Chris Dunford, has released the program into the public domain.

Conclusions

We started out talking about a CD-ROM that contains thousands of programs, and ended up focusing on several specific programs. Why? To show you that quality software really can be had for a reasonable price.

There are several methods of obtaining that software. Electronic bulletin boards across the country (including ours) carry those programs—you just have to find a BBS that has what you want, and then download it. For a large program, downloading can take some time, so the $6 PC-SIG charges per disk may be less than your connect-time charges, especially if you're calling long distance.

The PC-SIG CD-ROM would be a good investment for a medium-to-large-sized computer club. The hardware cost could

be shared among the members, who would then have access to thousands and thousand of programs.

The PC-SIG CD-ROM sells for $195; a CD-ROM player will set you back about $1000 at the present time, although prices will continue to drop as competition heats up, and volume production increases.

32-BIT MICROCOMPUTERS, the Z-386 model *80* and the Z-386 model *40,* are part of Zenith's Z-300 Desktop PC series. Both models feature a 32-bit memory bus that operates at 16 MHz and offer the following speed enhancements:

Use of "memory paging" results in faster operation by accessing large blocks of memory—2000 and 4000 bytes of information—at once. That minimizes the use of wait states, which slow a PC's performance by inserting idle time that allows the microprocessor to wait for memory to "catch up."

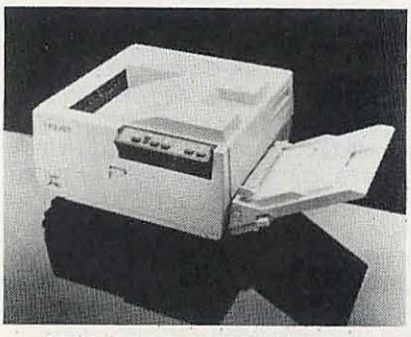
CIRCLE 18 ON FREE INFORMATION CARD

"Burst-mode refresh" increases system speed by refreshing multiple rows of memory at once. That reduces the amount of time that the microprocessor is occupied in refresh functions, increasing the amount of available computing time.

An optional "cache controller" board stores frequently accessed data in extremely fast static RAM (*R*andom *A*ccess *M*emory), thereby minimizing system wait states. The Z-386 PC's have three open 32-bit memory slots, allowing the use of the cache controller and memory cards.

The Z-386 model *80* (with an 80-megabyte hard disk drive) is priced at $7499.00; the Z-386 model *40* (with 40 MB of storage) costs $6499.00.—**Zenith Electronics Corporation,** 1000 Milwaukee Avenue, Glenview, IL 60025.

LASER PRINTER, the *Laserline 6,* features plug-in personality modules that enable up to three users to share a single printer. It also includes 15 resident, typeset-quality fonts and provides face-down, correct-order stacking of letter and legal paper.



CIRCLE 19 ON FREE INFORMATION CARD

Three different personality modules are available: The basic personality module is a one-port HP *Laser-Jet*-compatible version; the advanced module is a one-port HP *LaserJet Plus* compatible module, and the multi-user module is a threeport HP *LaserJet Plus* compatible module.

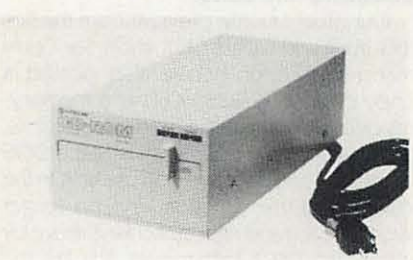
The *Laserline 6* is fully compatible with a wide selection of applications software, including Microsoft Word, Wordstar 2000, and Lotus 1-2-3.

The *Laserline 6* has a suggested retail price of $1995.00; the basic personality module has a list price of $200, the advanced module, $400, and the multi-user module, $600.00.— **Okidata,** 532 Fellowship Road, Mt. Laurel, NJ 08054.

CD-ROM DRIVE, the model *CDR-2500S,* is a stand-alone version of Hitachi's built-in model, which is equipped with cable and interface board to conect to IBM PC's.

The model *CDR-2500* is designed to be incorporated into a personal computer, while the earlier models, the *CDR-1502S* and the *CDR-2500S*—both stand-alone models—have their own power supplies and can be connected as external components.

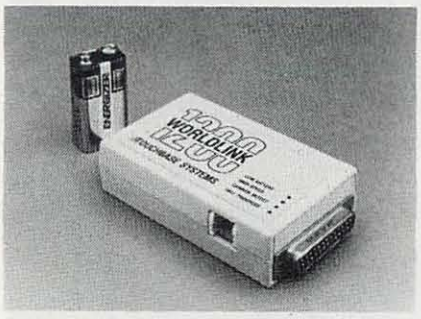
All three units offer 552 megabytes memory capacity, and a speed of 200 to 535 rpm (CLV) for single-sided disks. With high-speed random access, the models have a capacity of more than 1500 floppy disks, and are especially useful for a variety of data and information-storage operations.



CIRCLE 20 ON FREE INFORMATION CARD

The model *CDR-2500S* is priced at $1100.00, the model *CDR- 1502S,* $1000.00, and the model *CDR-1502S,* $1050.00.— **Hitachi Sales Corporation of America,** 401 W. Artesia Blvd., Compton, CA 90220.

MODEM, the *WorldLink 1200,* is battery-powered and Hayes-compatible. Features include: 1200/300 bps operation, auto-dial, auto-answer, pulse and tone dialing, LED indication of call progress, carrier detect, speed, and low battery.

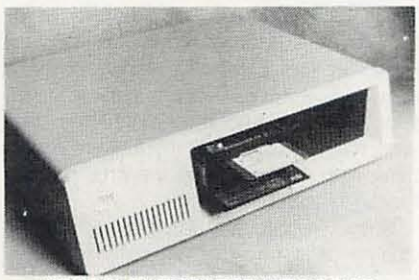


CIRCLE 21 ON FREE INFORMATION CARD

The *WorldLink 1200* supports both Bell 102/212A and CCITT V.21 and V.22 standards, so it is useful internationally. Optional acoustic cups allow full-duplex operation at both 300 and 1200 bps. List price is $199. **Touchbase Systems,** 16 Green Acre Lane, Northport, NY 11768.

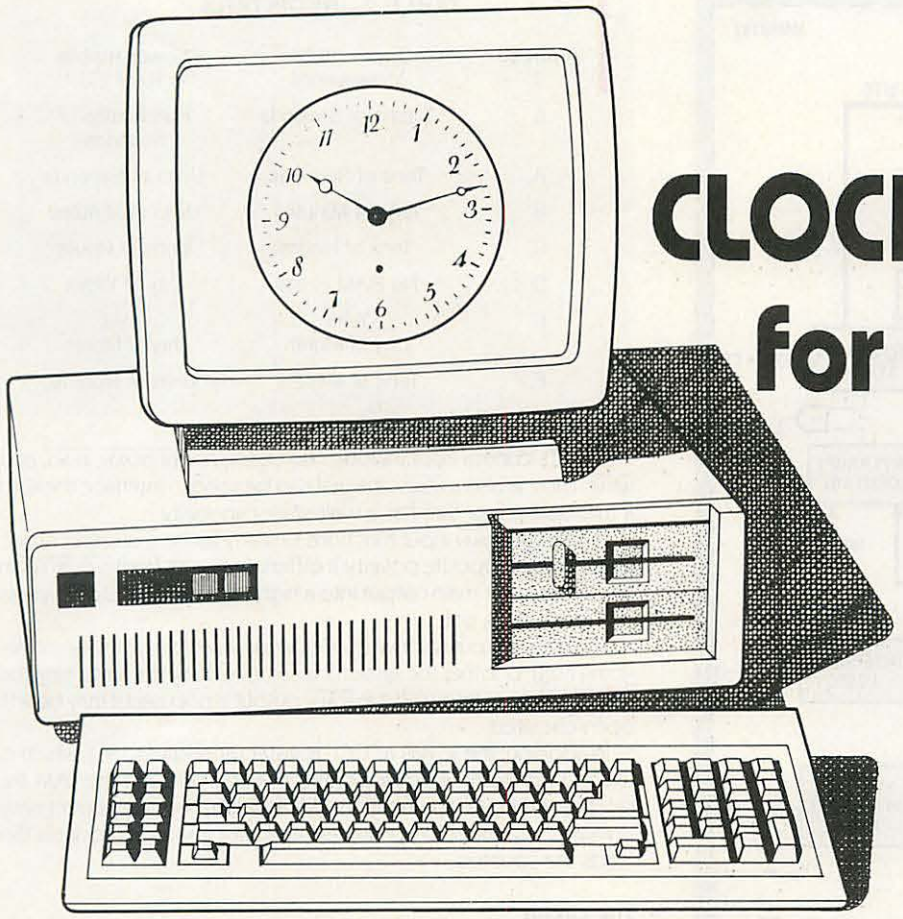
3.5-INCH DRIVE KIT is designed to convert desktop PC's to the smaller, yet higher storage-capacity format of 3.5-inch software.

The new model *ND354A* disk drive and kit are also designed for easy installation into the IBM PC, XT, AT and compatible personal computers, including the AT&T model *6300,* Compaq *Deskpro* and *Portable.* In addition, the drives are also fully compatible with the IBM *Convertible,* Toshiba's model *T1100, T1100 PLUS,* and *T3100* laptops.



CIRCLE 21 ON FREE INFORMATION CARD

Both the 3.5-inch drive and installation kit for 5.25-inch form-factor drive PC's will be sold together at the suggested retail price of $150.00.—**Toshiba America Inc.,** Information Systems Division, 2441 Michelle Drive, Tustin, CA 92680.



BUILD A CLOCK BOARD for YOUR PC

Build this inexpensive clock board and keep your IBM-PC (or compatible) on time and up to date— automatically!

VAUGHN D. MARTIN

The IBM-PC is a great machine, but it does have its quirks. For example, every time you turn it on, you have to enter the time and the date. That's no big deal—it's just a pain to have to do it every single time you use the computer.

Of course, you don't really have to enter the current time and date—you can just press the RETURN key. But then you won't be able to tell when you last worked on a file. And backup software may not work correctly, either.

However, there is a way to let the hardware do the drudge work for you—and that's what computers are for. All you need is a clock/calendar IC, a lithium battery, a few buffers and decoders, and a little software. The combination will take care of keeping your computer on time and up to date—you'll only have to enter the time and date when installing the clock.

The circuit was designed to work with the IBM-PC and compatibles; the PC board fits in the short slot. A kit of parts is available for under $50; by doing some judicious shopping, you can build the circuit for even less. The cost is less than that of other boards that contain expensive I/O ports and other features that you may not really need or want.

Basic flowcharts of software operation will be presented here; the kit includes a disk with several programs (CLOCKSET.EXE and READCLOC.EXE) that allow you to set and read the clock, respectively. In addition, we'll post the source code (which is written in Lattice C) on the RE-BBS, so you can customize it to your heart's content.

How it works

The circuit is based on an MM58167A real-time clock IC, manufactured by National Semiconductor. It requires extremely low power, so a three-volt lithium battery should easily last a year or more. A block diagram of the MM58167A is shown in Fig. 1.

The IC has several data, control, and address lines. The address bus is five bits wide, allowing access to a total of 32 locations. The contents of those locations are indicated in Table 1. The MM58167A also has a bi-directional eight-bit data bus.

Driving the IC is an oscillator, which requires two capacitors, a resistor, and a 32.768 kHz quartz crystal, which function together as

TABLE 1—CLOCK IC

Address					Contents
A4	A3	A2	A1	A0	
0	0	0	0	0	Counter—Ten Thousandths of Seconds
0	0	0	0	1	Counter—Hundredths and Tenths of Seconds
0	0	0	1	0	Counter—Seconds
0	0	0	1	1	Counter—Minutes
0	0	1	0	0	Counter—Hours
0	0	1	0	1	Counter—Day of Week
0	0	1	1	0	Counter—Day of Month
0	0	1	1	1	Counter—Month
0	1	0	0	0	RAM—Ten Thousandths of Seconds
0	1	0	0	1	RAM—Hundredths and Tenths of Seconds
0	1	0	1	0	RAM—Seconds
0	1	0	1	1	RAM—Minutes
0	1	1	0	0	RAM—Hours
0	1	1	0	1	RAM—Day of Week
0	1	1	1	0	RAM—Day of Month
0	1	1	1	1	RAM—Months
1	0	0	0	0	Interrupt Status Register
1	0	0	0	1	Interrupt Control Register
1	0	0	1	0	Counters Reset
1	0	0	1	1	RAM Reset
1	0	1	0	0	Status Bit
1	0	1	0	1	GO Command
1	0	1	1	0	STANDBY INTERRUPT
1	1	1	1	1	Test Mode

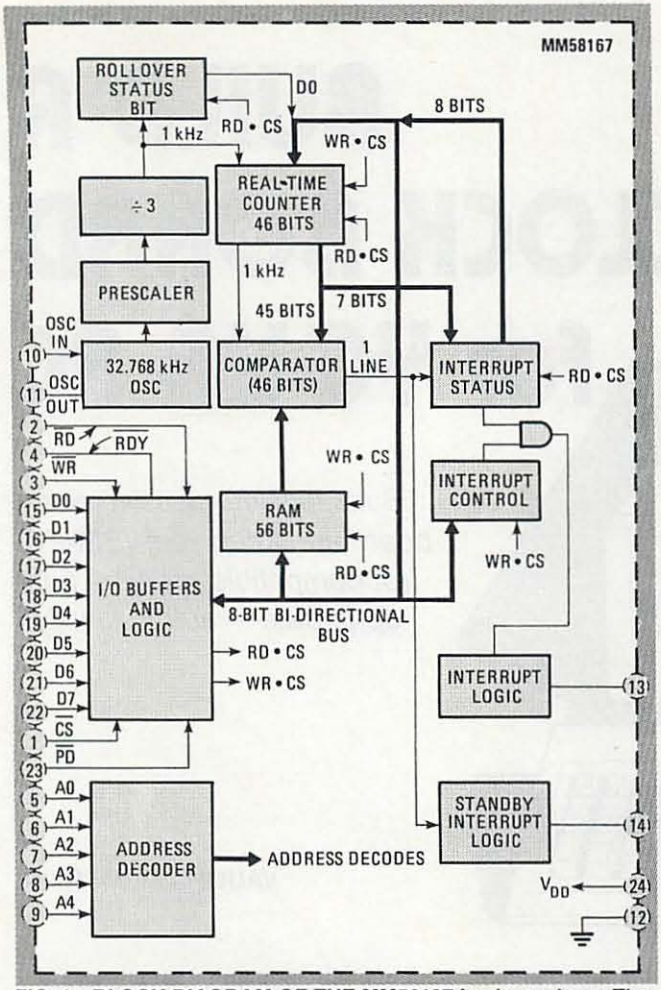


FIG. 1—BLOCK DIAGRAM OF THE MM58167 is shown here. The 56 bits of RAM can be used for generating alarm interrupts or as general-purpose storage.

a Pierce-type parallel-resonant circuit. The prescaler and the ÷32 sections provide a 1-kHz clock signal that drives the real-time counter, which consists of a 14-stage BCD counter. Each stage can be read from and written to; the counter keeps time in a 24-hour format.

A read-only rollover status bit signals when invalid data may have been read. Invalid data could be read if the counter incremented during a read (or between reads of successive locations.) A counter could increment because the counter chain is asynchronously clocked with respect to the system microprocessor (in this case, the IBM's 8088).

The clock IC's RAM contains fourteen four-bit nibbles that can be used for alarm interrupts or for general storage. In this project, the RAM is used for storage. The nibbles are accessed from the outside eight bits at a time; Table 2 shows how the nibbles are distributed in the MM58167's address space. Also note that some nibbles are not externally accessible: the low-order nibble at address 8 and the high-order nibble at address D. Note that the year is not available from the IC directly; it is tracked by the control software.

Referring back to Fig. 1, the comparator is a 46-bit device designed to compare values in RAM against the counters to provide an alarm interrupt. The alarm feature is not used in this project, but you could use it by writing the appropriate software, and by connecting the IC's interrupt output to one of the PC's interrupt lines.

Actually, the IC has two interrupt outputs: the main interrupt and the standby interrupt. The main interrupt is an active-high push-pull output. The standby interrupt is an active-low open-drain output. For the main interrupt, an eight-bit control register allows the user to select from one to seven interrupt rates (10 Hz, 1 Hz, etc.), as well as an alarm. The 8-bit status register (at address 10h) informs the user

TABLE 2—REGISTERS

Address	Upper nibble	Lower nibble
8	Milliseconds	No RAM Exists
9	Tenths of Seconds	Hundredths of Seconds
A	Tens of Seconds	Units of Seconds
B	Tens of Minutes	Units of Minutes
C	Tens of Hours	Units of Hours
D	No RAM exists	Day of Week
E	Tens Day of Month	Units Day of Month
F	Tens of Months	Units of Months

which one of the eight interrupts has occured.

The IC's control lines include $\overline{\text{CHIP SELECT}}$, $\overline{\text{POWER DOWN}}$, $\overline{\text{READ}}$, and $\overline{\text{WRITE}}$. There is also a $\overline{\text{READY}}$ line that can be used to interface the IC to a microprocessor that has a wait-state capability.

The $\overline{\text{POWER-DOWN}}$ input functions similarly to the $\overline{\text{CHIP-SELECT}}$ signal, albeit one of opposite polarity. It differs, however, from $\overline{\text{CHIP SELECT}}$ in that it forces the main output into a high-impedance state, whereas $\overline{\text{CHIP SELECT}}$ does not.

The $\overline{\text{READY}}$ output is active low; it becomes active on the negative-going edge of either the system's $\overline{\text{READ}}$ or $\overline{\text{WRITE}}$ signals (assuming the $\overline{\text{CHIP-SELECT}}$ input is low). If the $\overline{\text{READY}}$ output is not used it may be left open-circuited.

In addition, the IC has a "GO" register (at address 15h), which is used to set the time. To do so, first the counters and the RAM are reset by writing FF into locations 12h and 13h. Then the correct time is written into the appropriate registers. Last, a write to address 15h loads the counters.

The circuit

Figure 2 shows the complete schematic of the clock's interface circuitry. NAND gates IC1-a, IC1-b, IC1-d, and 3-to-8 line decoder IC5 generate the MM58167's $\overline{\text{CHIP-SELECT}}$ signal. Any time an I/O address ranging from 2C0h to 2DFh is read or written, that signal will go low.

Integrated circuits IC3 and IC4 are bi-directional buffers that give the system access to the clock IC's address and control lines (IC3) and its data lines (IC4). The data-bus buffer (IC4) is also selected by the pin-9 output of IC5, and the direction of transfer is controlled by IC1-c, which combines the system's MEMORY-READ signal (at edge-connector pin B12) with the $\overline{\text{I/O READ}}$ line (at pin B14).

The clock IC's $\overline{\text{READY}}$ signal is connected directly to the system's $\overline{\text{I/O READY}}$ line to inform the computer when valid data is available.

When the computer is turned off, the clock IC receives power from lithium battery B1 through diode D3, and diode D2 prevents battery power from trying to feed the computer's power supply. When the computer is turned on, five-volt power is supplied through diode D2 to the clock IC. Since that voltage is higher than the three volts supplied by the battery, D3 is reverse-biased, so no current is drawn from the battery. Therefore, the battery should last longer if the computer is used more. In any case, the battery is rated to supply power for a year before it needs to be replaced.

The network composed of D1, R3, and C5 ensures that the clock IC undergoes the correct power-up and power-down sequences. In particular, the $\overline{\text{POWER-DOWN}}$ line (pin 23) should be held low until all other lines are stable. The R3-C5 time constant is sufficient. Also, $\overline{\text{POWER-DOWN}}$ should go low as soon as possible after power is turned off. When power is turned off, the computer's five-volt supply begins to drop, so eventually the charge on capacitor C5 forward-biases diode D1, and that allows C5 to discharge through the computer's power supply. Diode D1 is a germanium type, to keep the voltage drop across it low.

Construction

Our prototype was built on a printed-circuit board, foil patterns for which are shown in PC Service. You can also purchase an etched

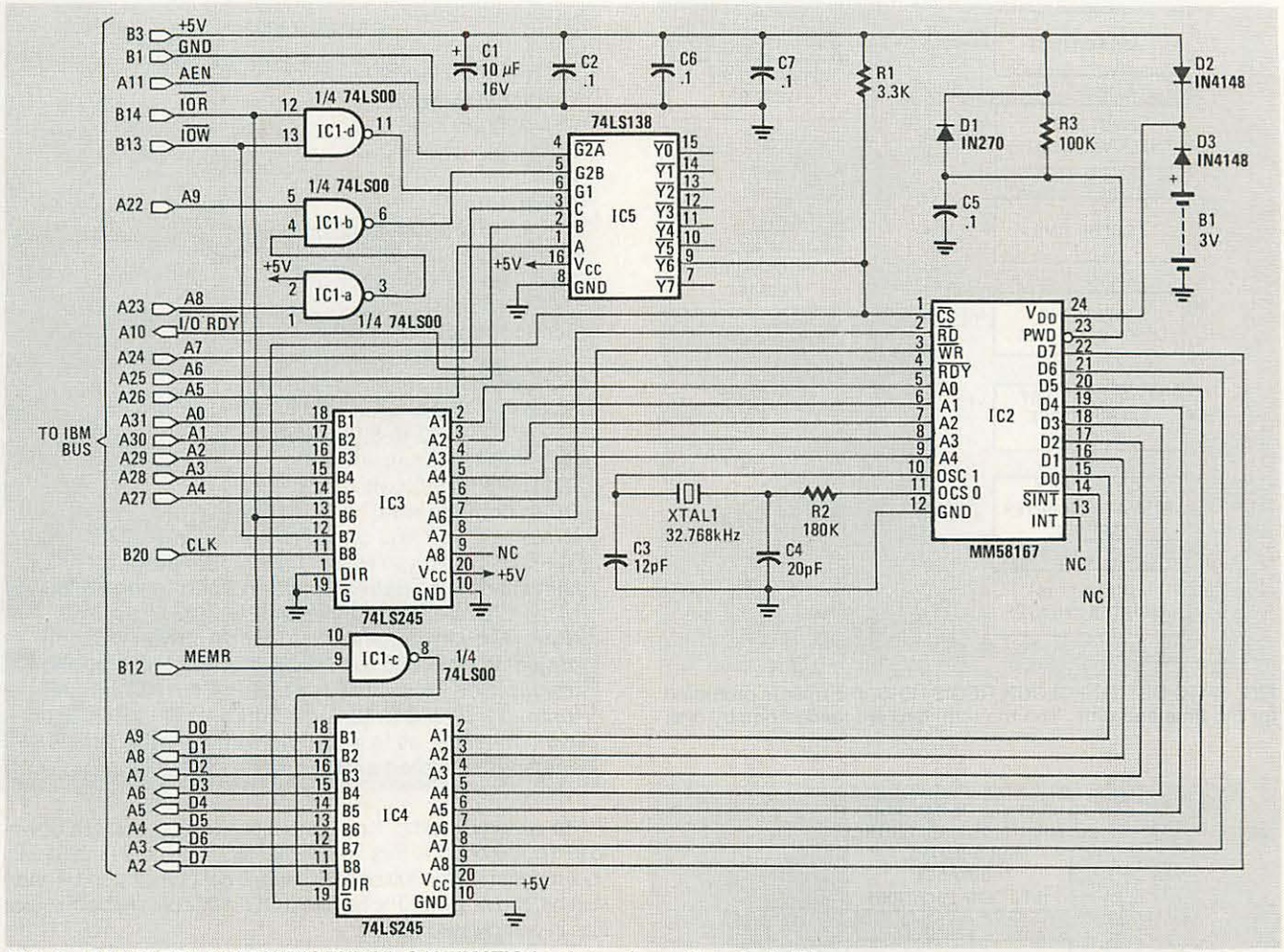


FIG. 2—COMPLETE CLOCK/CALENDAR SCHEMATIC is shown here. The clock IC's registers are accessed at the 32 locations beginning with 2CØh.

and drilled board (with gold-plated contacts) from the source mentioned in the Parts List. If you etch your own board, note that it is double-sided, so make sure that all feedthroughs are soldered on both sides of the board.

If you use our PC board, refer to Fig. 3, the parts-placement diagram, to stuff the board. Make sure that you mount the polarized capacitors correctly, as well as the diodes and the IC's. Check your work carefully.

Software

Two programs control operation of the clock board. The CLOCKSET program, outlined in Fig. 5, is used to set the clock (and to reset it when a time change occurs, or when the battery is changed.) When the program runs, it prompts the operator for the date, which is then checked. If the date is correct, the program prompts for the time, which is also checked. Entry of an invalid date or time causes the program to ask for the desired value again; the process repeats until a correct value is entered.

When the program has the correct values, it goes into a loop that consecutively sets the valid time and date values into the appropriate clock-IC registers.

The READCLOC program, outlined in Fig. 6, reads all the time and date registers from the clock IC. Because the IC's alarm feature is not used, several RAM locations (inside the MM58167) are used to keep track of the current year, as well as the month when the clock was last read. Then, each time the clock is read, the last month is compared to the current month. If the last month read is larger than the current month, it is assumed that the a new year has begun, so the year counter is incremented and saved.

The READCLOC program reads the status register each time to see whether the clock changed while the regeisters were read. If so, the registers are read again. The process continues until the status register indicates that valid data has been read. Before display, both date and time are checked for validity. If either is invalid, then an error message and a default time and date are displayed.

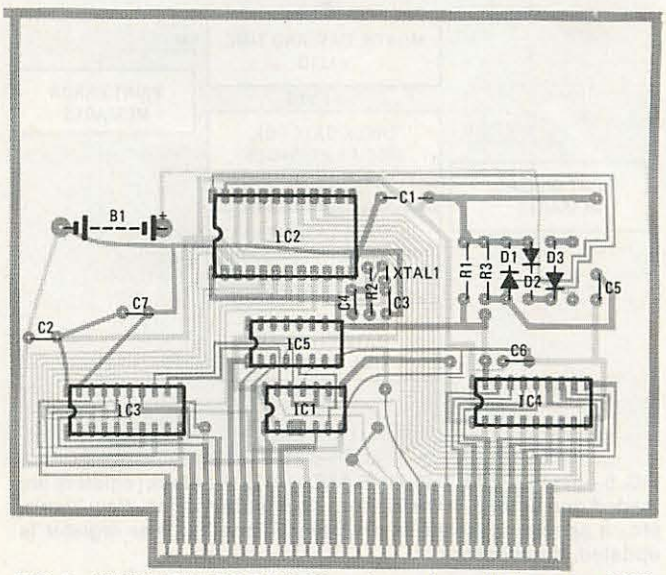


FIG. 3—STUFF THE PC BOARD as shown here. Make sure all IC's are inserted correctly, and that the polarity of the battery is also correct.

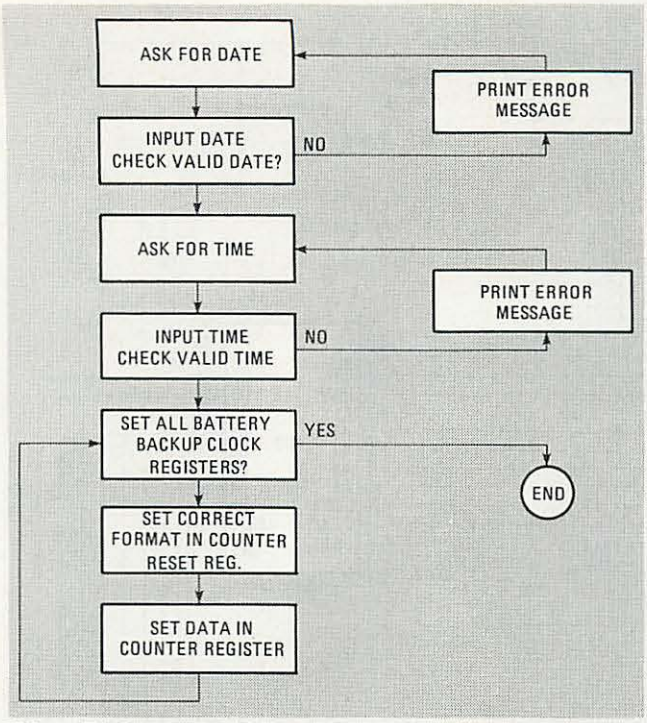


FIG. 4—TO SET THE CLOCK REGISTERS, the user is prompted for the time and date. The the registers are loaded one by one.

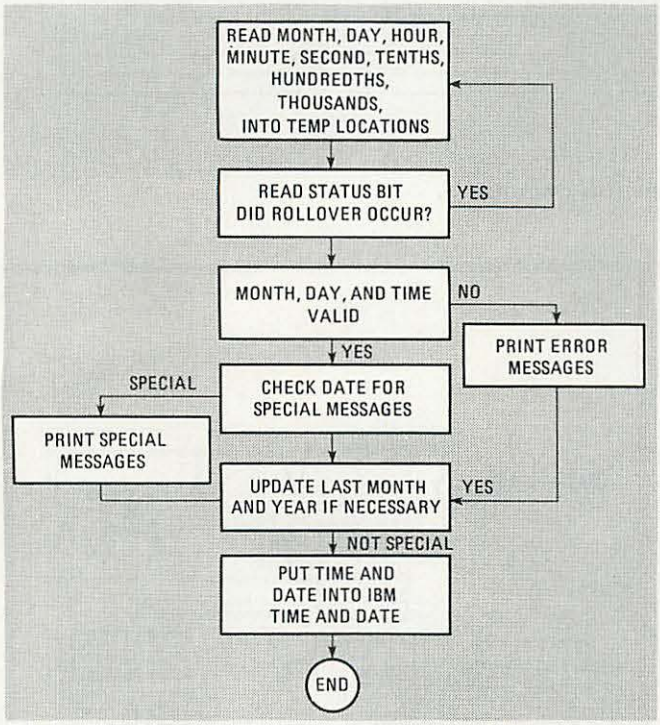


FIG. 5—TO DISPLAY THE TIME AND DATE, the clock registers are loaded one by one. If the current date is Christmas, New Year's, etc., a special message is displayed. Then the year register is updated, if necessary.

If time and date are valid, the program checks for a special date (New Year's Day, St. Valentine's Day, the 4th of July, Christmas, etc.). If the current date is one of those dates, an appropriate message ("Happy New Year," for example) is displayed, as are the time and date. Also the time and date are used to set the IBM-PC's time and date memory locations.

If you'd like more information about either program, or if you'd like to customize either for a special application, you can download the source code files from the RE-BBS. Call 516-293-2283 with your modem set for 300 or 1200 baud, 8 data bits, 1 stop bit and 1 start bit, and no parity. The file IBMCLOCK.ARC contains both source files in compressed format.

PARTS LIST

All resistors are ¼-watt, 5% unless otherwise noted.
R1—3300 ohms
R2—180,000 ohms
R3—100,000 ohms
Capacitors
C1—10 μF, 16-volt, tantalum
C2, C5, C6, C7—0.1 μF, 25-volts, disc
C3—12 pF silver mica
C4—20 pF silver mica
Semiconductors
IC1—74LS00 quad NAND gate
IC2—MM58167A real-time clock
IC3, IC4—74LS245 eight-bit bi-directional buffer
IC5—74LS138 3-to-8 decoder
D1—1N270 germanium diode
D2, D3—1N4148 switching diode
Other components
XTAL1—32.768 kHz crystal (Digi-Key no. X32768)
B1—3-volt coin-type lithium battery (Digi-Key no. P142)
Miscellaneous: Battery holder (Digi-Key no. BH906-ND), PC board, wire, solder, etc.
Note: A disk containaing driver software for this project is available for $12 ppd from Specialty Electronics Services, Inc., P. O. Box 680712, San Antonio, TX 78268-0712. In addition, a PC Board is available ($12), as is a complete kit of parts ($49.95), and an assembled and tested version ($59).

Installation

There's nothing to installing the PC board physically: Just remove power and insert the board into an empty slot. Then run the program CLOCKSET, which will ask you for the current time and date; and last run READCLOC, which will set the time for DOS. You can include READCLOC in your AUTOEXEC.BAT file to set time and date automatically every time you boot up.

Chances are extremely slight that you'll experience any problems with the board, assuming you followed good construction techniques. If you do have a problem, remove the board, and make sure that the IC's and diodes are oriented correctly, and that all components are soldered well.

If the board appears to be OK, the clock board's I/O-port usage may be conflicting with some other board in your system. Remove all boards that aren't absolutely necessary and try again. If the clock board works now, you've begun to isolate the problem. To make the board compatible with your other hardware, you'll have to change the I/O port of one or the other. Most manufacturers provide jumper blocks or switch settings to change I/O ports. If you want to change the clock board's I/O ports, cut the trace leading from pin 9 of IC5 (the 74LS138), and connect another output of the IC to the cut trace. To accommodate the new port, you'll also have to recompile the operating software.

Before going to such drastic lenghts, realize that it's possible, although unlikely, that the control software conflicts with some other software in your system. Try booting from a clean DOS diskette (one with no memory-resident programs), and then running CLOCKSET and READCLOC. If that solves the problem, experiment with your usual AUTOEXEC.BAT file. Try eliminating your RAM-resident programs one by one and rebooting until the problem goes away. Altering the loading order may solve the problem.

BUILD THE MC 68000

TIM AND HANS SCHRADER,
MANFRED KOENIG, HAGEN VOELZKE

Some people say that the day of the hacker is gone—that no one really wants to build his own computer—that people are content to plug keyboard and monitor into the back of a machine, insert a disk, and start computing.

We don't buy it. We think that there is more than one person interested in building his own computer from the ground up, learning every detail about it, customizing it, making it do what he wants it to do, not what IBM or Apple or Commodore says it should do. So, during the next few months, we'll be presenting a series of articles on building a 68000-based machine.

A 68000? Not an 8088? No—definitely not! We're developing Intel-itis! So we want to look at a different microprocessor family. Are we anti-Intel? Pro-Motorola? Neither. But we want to facilitate discussion.

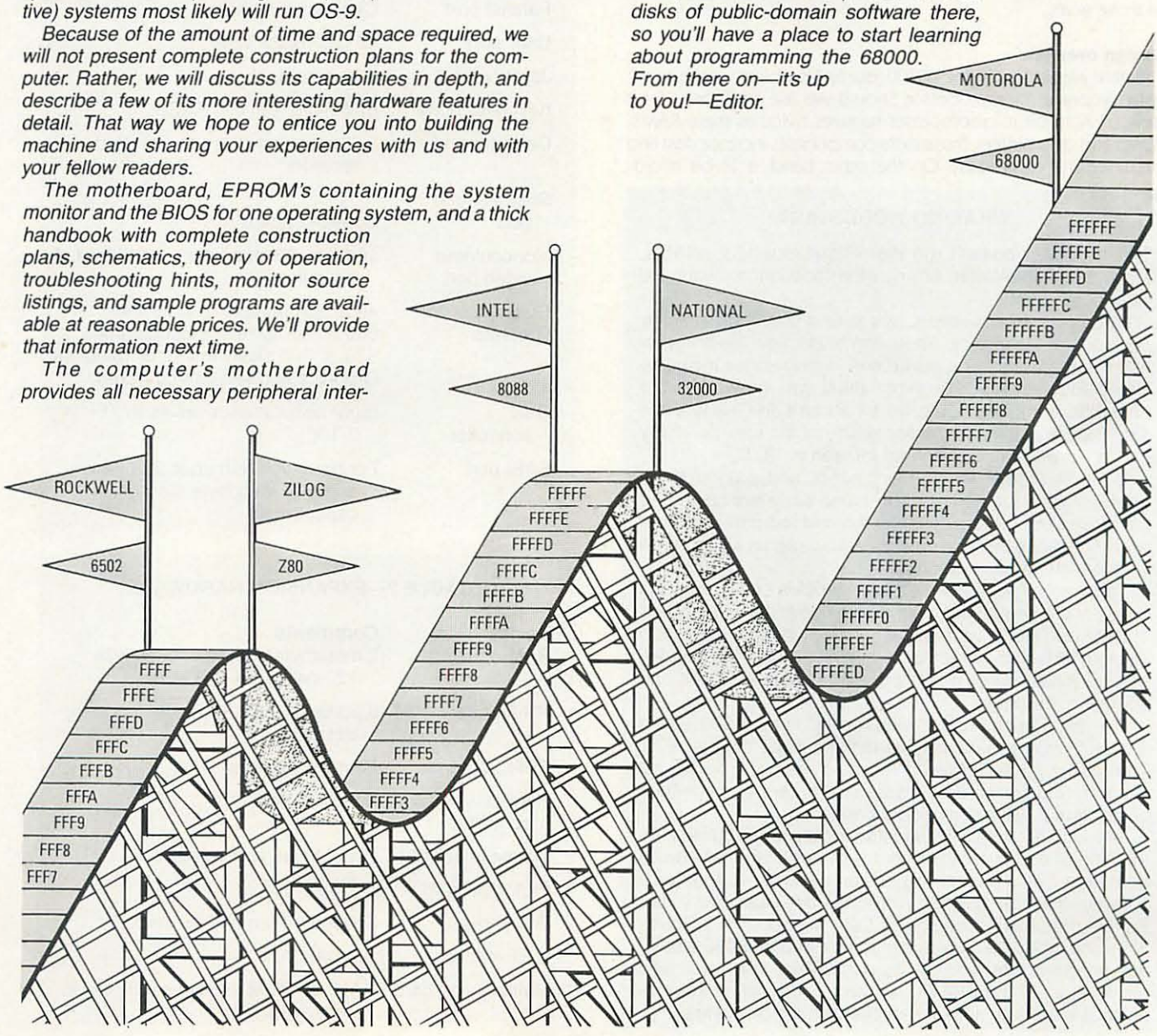
In order to do so, we will present plans for building a computer that runs the CP/M-68K and OS-9 operating systems. Most people are familiar with CP/M from its long use with (ironically) Intel (8080) and Zilog (Z80) microprocessors. Fewer people are familiar with OS-9. It has been around nearly as long as CP/M; it was originally written for the 6809 microprocessor. The Radio Shack Color Computer runs OS-9, as do a number of proprietary systems. And the upcoming CD-I (Compact Disk Interactive) systems most likely will run OS-9.

Because of the amount of time and space required, we will not present complete construction plans for the computer. Rather, we will discuss its capabilities in depth, and describe a few of its more interesting hardware features in detail. That way we hope to entice you into building the machine and sharing your experiences with us and with your fellow readers.

The motherboard, EPROM's containing the system monitor and the BIOS for one operating system, and a thick handbook with complete construction plans, schematics, theory of operation, troubleshooting hints, monitor source listings, and sample programs are available at reasonable prices. We'll provide that information next time.

The computer's motherboard provides all necessary peripheral interfaces (disk and video controllers, keyboard interface, serial and parallel ports, etc.) In addition, much expansion hardware is available, including RAM cards, an IEEE-488 interface, speech card, D/A and A/D converters, and more. Further, many professional programming languages are available, including BASIC, C Pascal, LISP, FORTRAN, etc.

Last, we've set up a special section of the R-E BBS (516-293-2283) for readers to share problems, hints, complaints, congratulations, etc. We've also posted several disks of public-domain software there, so you'll have a place to start learning about programming the 68000. From there on—it's up to you!—Editor.



Apple's *Macintosh*, Commodore's *Amiga*, and Atari's *ST* all have one thing in common: the 68000 microprocessor that provides those computers with their smarts. Unfortunately, all three machines have closed architectures and proprietary hardware and software. That makes it hard to build add-on hardware, as well as software.

The IBM-PC family has one big advantage over all the 68000 machines: its open architecture. Every detail of every machine, adapter board, and even BIOS ROM listings have been published by IBM in a series of Technical Reference manuals.

So we felt that it was time to introduce a computer system with the best of both worlds: an open-architecture machine based on the 68000. In doing so, we had several design goals:

- The basic unit should provide all necessary hardware to get a system up and running, but the design should also be flexible enough to handle advanced operating systems and hardware.
- Assembly and testing should be simple enough that the amateur computerist would be able to get the system running without expensive test equipment.
- All components should be readily available; no expensive or hard-to-find parts should be used.
- The price of the computer should be competitive with that of the closed-architecture machines.

We believe that the computer described here meets or exceeds all those goals.

Design overview

Before we settled on the 68000, our first problem was to select an appropriate microprocessor. Should we use an 8- or a 16-bit device? A 16-bit microprocessor requires twice as many RAM's, ROM's and data buffers; those extra components increase cost and circuit-board complexity. On the other hand, a 16-bit microprocessor can handle data twice as fast as an 8-bit device. Benchmark tests showed that an 8086 microprocessor would not satisfy our performance needs, but that a 68000 would, because it has a 32-bit internal data path.

After settling on the 68000, there were still many things to decide. We wanted the system to be able to accomodate as many different types of hardware as possible, so that users could avoid the anguish of accidentally buying incompatible equipment (keyboard, monitor, disk drives, etc.) Therefore our motherboard has many ports for interfacing a wide variety of peripherals, as shown in

WHAT, NO WORDSTAR?

This computer doesn't run WordStar, Lotus 123, dBASE, MacDraw, AppleWriter, or any other popular software. So what good is it?

To answer that question, let's take a brief look at some microcomputer history. About ten years ago the first personal computer kit was advertised in magazines including **Radio-Electronics.** The Altair 8800 was greeted at the time with smugness: "Cute, but what can it *do*?" History has since shown that the personal computer can do many things, very few of which were forseen in 1976.

Many of today's leading engineers and programmers (and editors!) got their start on those early machines; the hardware and software tinkering they did has provided them with knowledge that has proven its worth again and again in working with other systems.

Times change, of course, and it wouldn't be worthwhile publishing information on building a computer with a few K of RAM and ROM, and only toggle switches for input, and discrete LED's for output. Ergo this 68000-based computer, several thousand of which are already live and well and operating in Europe.

The computer can be assembled for under $1500, which is about what a maximally configured Altair cost in 1976. The lesser price, however, includes memory, peripheral support, and software that is several orders of magnitude better than what was available back then.

Although it doesn't run popular applications software, it's the kind of computer the serious student can learn much from, and it also has the expansion capacity and systems software that the scientist and engineer uses every day. Further, Phoenix Technologies (320 Norwood Park South, Norwood, MA 02062) recently announced an 8088 emulation program that runs on various 68000 machines, and allows them to run IBM-PC software. So building this machine is in no way a lesson in planned obsolescence.

TABLE 1—ON-BOARD HARDWARE

Hardware	Comments
CPU	8-MHz 68000 or 68010
RAM	128K or 512K, expandable to 16 megabytes
ROM	64K on board (32K monitor and 32K for BIOS)
BUS	Eight fully buffered expansion slots
Serial port	Up to 19,200 bps
Parallel port	Centronics standard
User port	16 bits (6522 VIA)
Joystick port	Standard analog
Keyboard ports	IBM-PC or parallel ASCII
Cassette port	3,600 bps, interface to standard recorder
Stereo sound port	Speech capability
Monochrome video port	16 MHz, 80 characters × 25 lines, 4 attributes
RGB video port	40 or 80 characters × 25 lines
Graphics	640 × 200 pixels (monochrome), 320 × 200 pixels in four of 16 colors Graphics and text can be mixed.
Disk controller	Eight simultaneous drives (8", 5-1/4", 3-1/2")
SASI port	For hard disk with up to 32 heads and 100 megabyte storage capacity

TABLE 2—EXPANSION HARDWARE

Device	Comments
RAM card	2 megabytes,no wait states with 120-ns 41256 at 8 MHz
RS-232 card	8 ports for MIDI, modems, printers, terminals
EPROM burner	Four ZIF sockets
Hard-disk controller	For SASI port
Mouse interface	With Mouse and software
Prototype card	
D/A and A/D	Several 10- and 12-bit cards
IEEE 488	Bus interface
Multifunction card	RAM, EPROM, I/O lines (28), clock, centronics port

MOTOROLA *vs.* INTEL

In the mid 1970's Intel Corporation quietly introduced the 8008 microprocessor. The device made it possible, for the first time, to build machine controllers that were programmable via electronic—not mechanical—means.

Shortly thereafter, MOS Technology and Motorola introduced microprocessors of their own: the 6502 and the 6800, respectively. Since that time, Motorola's original microprocessor has led to several generations of increasingly powerful devices, including several families of controllers, the general-purpose 6809, and the 68000 family, heart of the Apple *Macintosh*, the Commodore *Amiga*, and the Atari *ST*, as well as a number of UNIX-based systems, and other proprietary systems.

Of course, Intel didn't rest on its laurels. The 8008 soon gave way to the 8080, and then the 8088, heart of the IBM-PC. By some accounts the 8088, and its more powerful siblings, the 8086, the 80286, and the 80386, are the most powerful microprocessors in existence.

That's not the case, however. In fact, it can be argued that the 68000, and its more powerful siblings, the 68010, the 68020, and the 68030 are more versatile, easier to use, and more powerful than corresponding members of the 8088 family. So we chose the 68000 for this machine, rather than an Intel 8088-series device, and here are some of the reasons why.

For starters, the basic 68000 has equal access to all 16 megabytes (4 gigabytes for the 68020) of memory, whereas the 8088 family can address only 64K at a time through the use of segment registers that must be specially loaded by the programmer, the linker, or both. Later devices in the Intel family (the 80286 and the 80386) are not as restricted as the earlier devices in their ability to access large chunks of memory, but, as of this writing, software incompatibility has prevented widespread use of the expanded facilities.

In addition, the 68000 has a more highly integrated internal structure; that integration makes life much easier for the programmer. The 68000 has eight 32-bit data registers, any of which may be used as an accumulator, index counter, etc. The 68000 also has seven 32-bit address registers that, likewise, are truly general purpose.

The 8088 family, by contrast, has a dedicated accumulator and separate counting, index, and data registers. Different registers access different parts of memory, depending on the segment registers that modify them. The programmer must at all times keep track of both data and segment registers, and how the contents of those registers are affected by which instructions.

The 68000's instruction set is quite regular; the MOVE instruction, for example, can transfer values between any combination of CPU registers, memory, and peripheral devices. The 8088 family, by contrast, has separate LOAD, STORE, IN, and OUT instructions that are not all valid in all address modes—and that's one more "feature" that makes life difficult for the programmer.

Furthermore, successive generations of the 68000 family add facilities, but remain highly compatible with the earlier generations. Often a later-generation device can be inserted directly into the socket of an earlier device, and the user can immediately benefit from the added facilities.

Each generation of the Intel family, on the other hand, has introduced new modes that are incompatible with the original mode. So software developers are forced to re-develop applications from scratch, or to ignore the new modes altogether. The 80386 will remedy some of the problems mentioned, but control software that can make use of all its facilities is not likely to be seen before 1988. However, multi-user, multi-tasking operating systems (OS-9 and CRTX) are available for this machine right now.

TABLE 3—OPERATING SYSTEMS AND PROGRAMMING LANGUAGES

Software	Comments
MONITOR	32K, with editor, monitor, symbolic assembler, and debugger (contained in two on-board EPROM's).
CP/M-68K	Version 1.2, including C compiler
OS-9/68K	Realtime, multiuser, multitasking
CRTX	Realtime, multiuser, multitasking
MODULA 2	Pascal's control structures, C's power and speed
FORTH	Enhanced FORTH ('79 and '83 standards) with many 32-bit operations, editor and high-res graphics commands
C	Included with CP/M
XLISP	Public-domain interpreter
FORTRAN 77	Compiler
PASCAL	Compiler
BASIC PLUS	Interpreter
C	Whitesmith
FBASIC	Fast BASIC compiler, MBASIC compatible
GEDIT	Screen-oriented program editor, menu-driven
GRED	Joystick/mouse-controlled graphics program
PHO	Phoneme editor for speech card
CEDIT	Editor with built-in calculator
RAB	Memory-resident utility program with calculator, clock,memo pad, etc.
DU	Disk utility

Table 1. To keep the cost of the peripherals as low as possible, we made the system compatible with inexpensive IBM-PC clone components (keyboard, power supply, monitor, etc.).

We chose the 6845 (which, by the way, is used in the IBM-PC's color and monochrome display adapters) for video control. The screen can be switched, under software control, between text and high-res graphics displays. In monochrome text mode, 25 lines of 40 or 80 characters, each with a resolution of 8 × 10 pixels, can be displayed. The monochrome graphics mode has 640 × 200 freely programmable pixels; through hardware or software scrolling, a 1024 × 1024 matrix may be controlled. In color mode, you can display text as 40 characters × 25 lines, or graphics in 16 colors, from a 320 × 200 pixel matrix.

A DMA channel connected to the video RAM allows for superfast graphics; up to 32 graphics pages can be defined. All important video signals (including the discrete RGB signals, SYNC and HSYNC, and their complements) are available at the video port, making it simple to interface just about any kind of monitor.

Seldom contained on any microcomputer motherboard is a floppy-disk controller. However, we have included a 1793 drive controller and a 9229 data separator. Just about any standard drive can be interfaced through one of two buses. Bus 1 is for 5¼" and 3½" drives; bus 2 is for 8" drives. As many as four drives, single or double sided, can be connected to each bus and configured via software as single or double density, with 35, 40, 77, or 80 tracks. The motherboard also has a SASI hard-disk controller.

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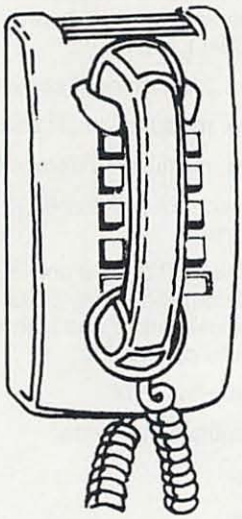

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27256	32Kx8	250 ns	4.96	
27128	16Kx8	250 ns	3.77	8087
27C64	8Kx8	200 ns	4.52	80287-8
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Assorted interfaces

For flexibility, several kinds of keyboards can be accomodated: serial ASCII, parallel ASCII, and IBM-PC. Both Centronics and RS-232C ports are included, as is a freely-programmable 16-bit user port. An analog joystick port and a stereo sound port are also included; the latter can be used for speech synthesis, with the addition of a speech/clock card.

For adding your own or commercial hardware, the system includes eight expansion slots. A sample of the commercially available hardware is shown in Table 2.

Software

You can get the system up and running simply by building the motherboard and adding a keyboard and a monitor (or an RS-232 terminal). The system attempts to boot from floppy disk, but if you push the ESC key during the boot process, you enter the ROM monitor. From there you can examine and change memory locations, use the built-in symbolic assembler, trace programs, etc.

Of course, eventually you'll want to add disk drives and write programs in a high-level language. The CP/M-68K operating system comes with an assembler/editor/debugger package, and the Digital Research C compiler. Many other editors, programming languages, and utilities are available, as shown in Table 3.

General remarks

About 2000 systems have been assembled since the computer was introduced in Europe in fall 1984. Interest groups sprouted all over Germany, and, based on the experiences of users there, a new motherboard was designed that corrected several flaws in the original.

Building the motherboard and peripheral cards is straightforward. However, construction does require meticulous attention to numerous small details. The handbook that accompanies the motherboard and EPROM set contains instructions for novice kit builders, as well as step-by-step instructions for testing each sub-system as you bring the computer up.

Next time we'll discuss hardware features and construction; the final article will discuss software.